Decadal Climate Prediction at GFDL

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1. Motivation and nature of decadal prediction
2. GFDL Decadal Prediction System and initial skill assessments
3. Future directions and critical issues

Motivations for decadal prediction efforts

- **Strong desire for climate predictions and projections on time scales of decades and regional spatial scales**
  - **Water resources, agriculture, extremes**

- **Concerns about the possibility of abrupt climate change**
  - **Ocean circulation, drought, biogeochemical cycles**

- **Potential benefits of moving toward unified modeling and prediction across time scales**

- **Better understanding of decadal variability is critical for detection and attribution**

Motivating examples:

1. Atlantic ocean decadal temperature variations with impacts on drought, hurricanes

2. Rapid decadal-scale loss of Arctic sea ice

3. Drought, such as Sahel drought of 1970s or SW US drought

For each case … how much was a response to radiative forcing and how much was internal variability? And to what degree can they be predicted?

Drivers for decadal climate variability

Decadal climate variations composed of at least two components:

- ***Internal variability of the coupled climate system***

- ***Response of the climate system to external forcing changes (greenhouse gases, etc)***

➔ **Most climate change projections typically focus solely on the response to radiative forcing changes.**

Key question: Can we produce better predictions of climate variations and change over the next decade or two if we use information describing the initial condition of the climate system in addition to estimating the response to radiative forcing changes?

Paradigm: There are decadal-scale oceanic variations that may be predictable and of climatic relevance, such as changes to the Atlantic Meridional Overturning Circulation (AMOC).

Components of Dynamical Prediction Systems

- **Observing Systems**
- **Assimilation Systems**
- **Models**
- **Changing radiative forcing**

Initial Value Problem
(synoptic to seasonal prediction)

Boundary Value Problem
(multi-decadal to centennial projection)

Decadal Prediction

Goal: ***Unified system for predictions and projections from seasonal to decadal to centennial time scales***

GFDL Decadal Prediction System and Experimental Design

MODEL:

- Currently use the GFDL CM2.1 model (2^o atm,1^o ocn; Delworth et al., 2006)
- Transition to GFDL CM2.5 high-resolution model (50 Km atm, 8-27 Km ocn; Delworth et al., 2012)

INITIAL CONDITIONS- Ensemble Coupled Data Assimilation (ECDA) Reanalysis (Zhang et al., 2007)

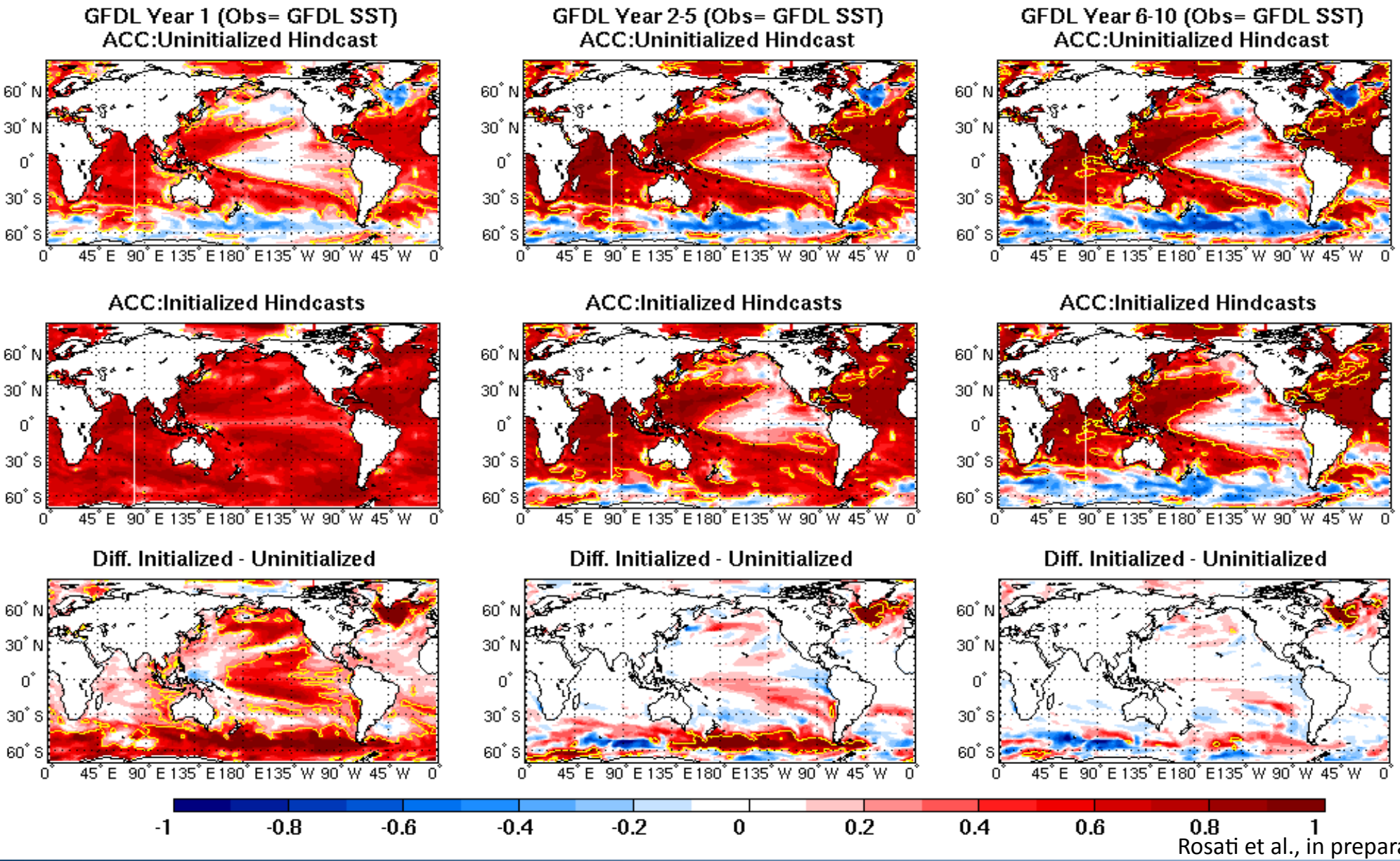
- Atmosphere - NCEP Reanalysis2 (T,u,v,ps)
- Ocean - xbt,mbt,ctd,sst,ssh,ARGO
- Radiative Forcing - GHG, Solar, Volcano, Aerosol

INITIALIZED RUNS - 10 member ensembles, starting Jan every year from 1960-2012 for 10 years (total of > 5000 model years); use observed estimates of radiative forcings 1960-2005, RCP 4.5 thereafter

UNINITIALIZED RUNS – 10 member ensembles, from 1861-2040; use observed estimates of radiative forcings 1960-2005, RCP 4.5 thereafter

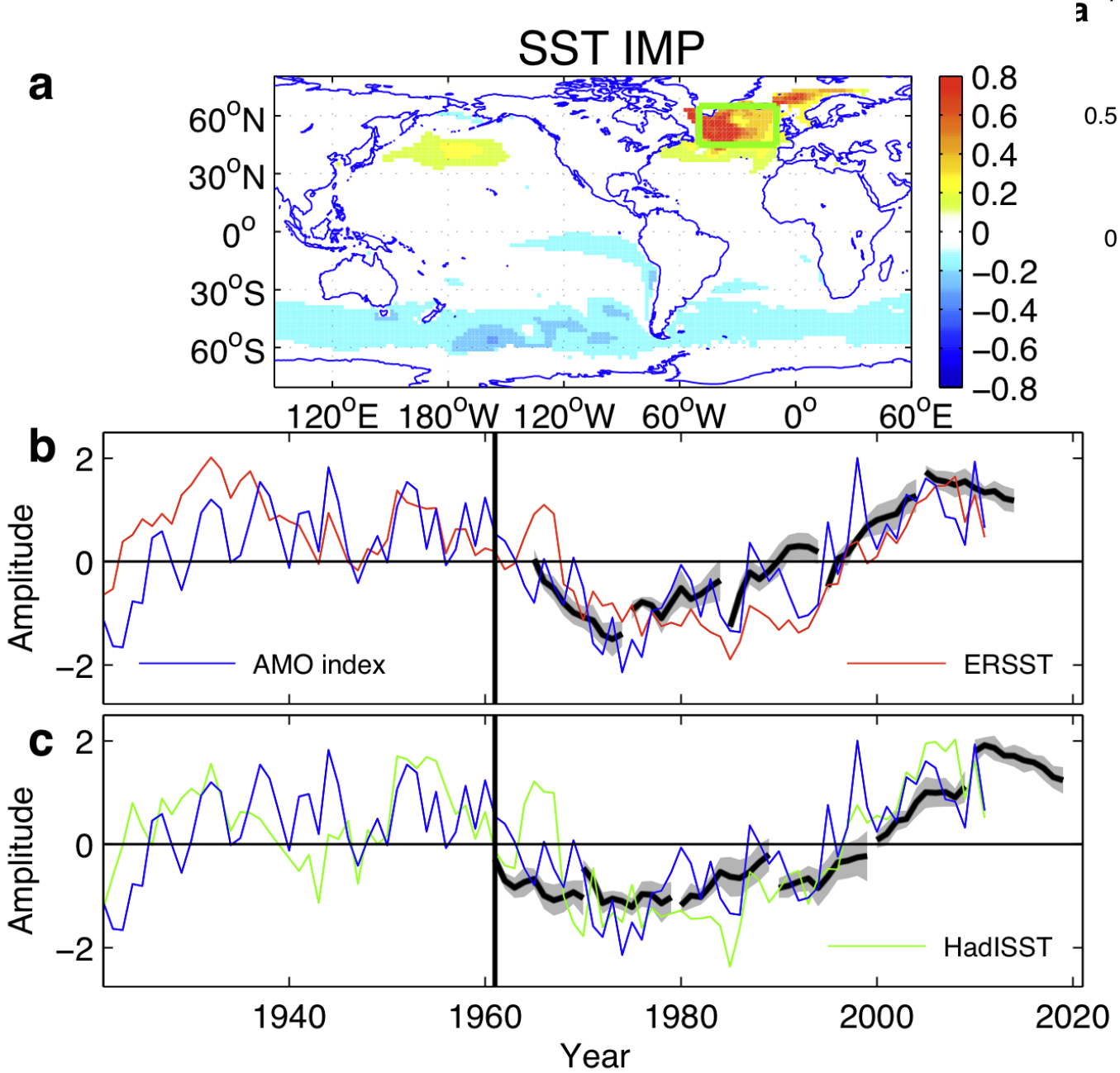
Model output available at http://nomads.gfdl.noaa.gov:8080/DataPortal/cmip5.jsp

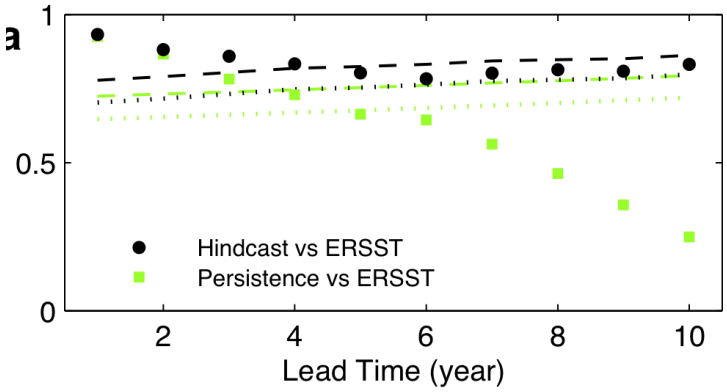
Anomaly correlation for SST



Rosati et al., in preparation

Most predictable pattern from APT (average predictability time) analysis resembles Atlantic Multidecadal Variability/Oscillation



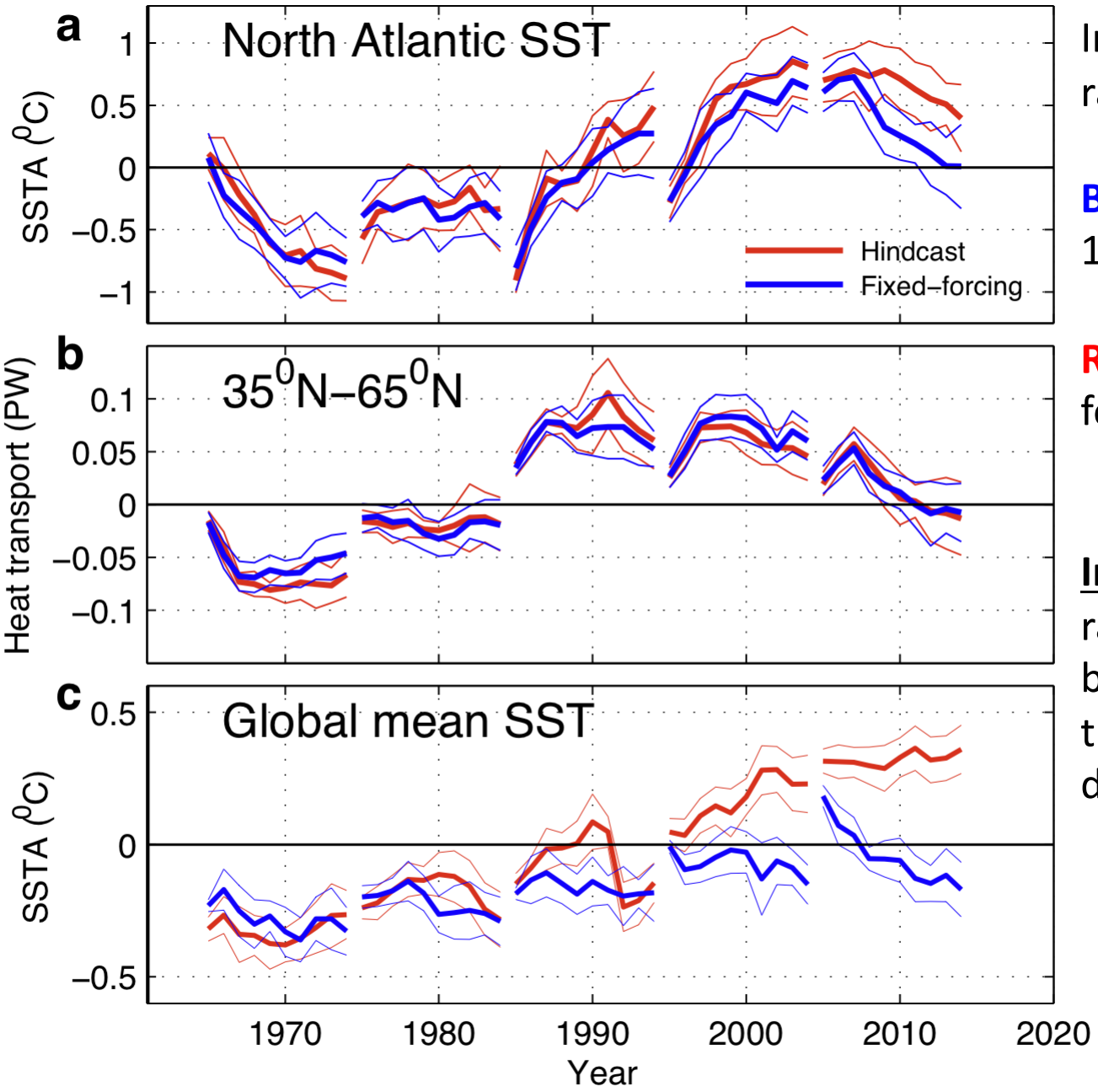


Yang et al., submitted

There are also indications of possible predictability of Atlantic hurricane activity on multi-year time scales, but much more work is needed related to:

- *role of radiative forcing*
- *changing observing system*
- *shortness of observed record*

Vecchi et al., in preparation



Initialized forecasts using different radiative forcing:

Blue curve: radiative forcing fixed at 1960

Red curve: "observed" radiative forcing, varying with the year

Implication: For global scale the radiative forcing quickly dominates, but on regional scales the effects of the initial conditions can persist for a decade

Initialization has a much larger potential impact on regional/basin scale than on global scale.

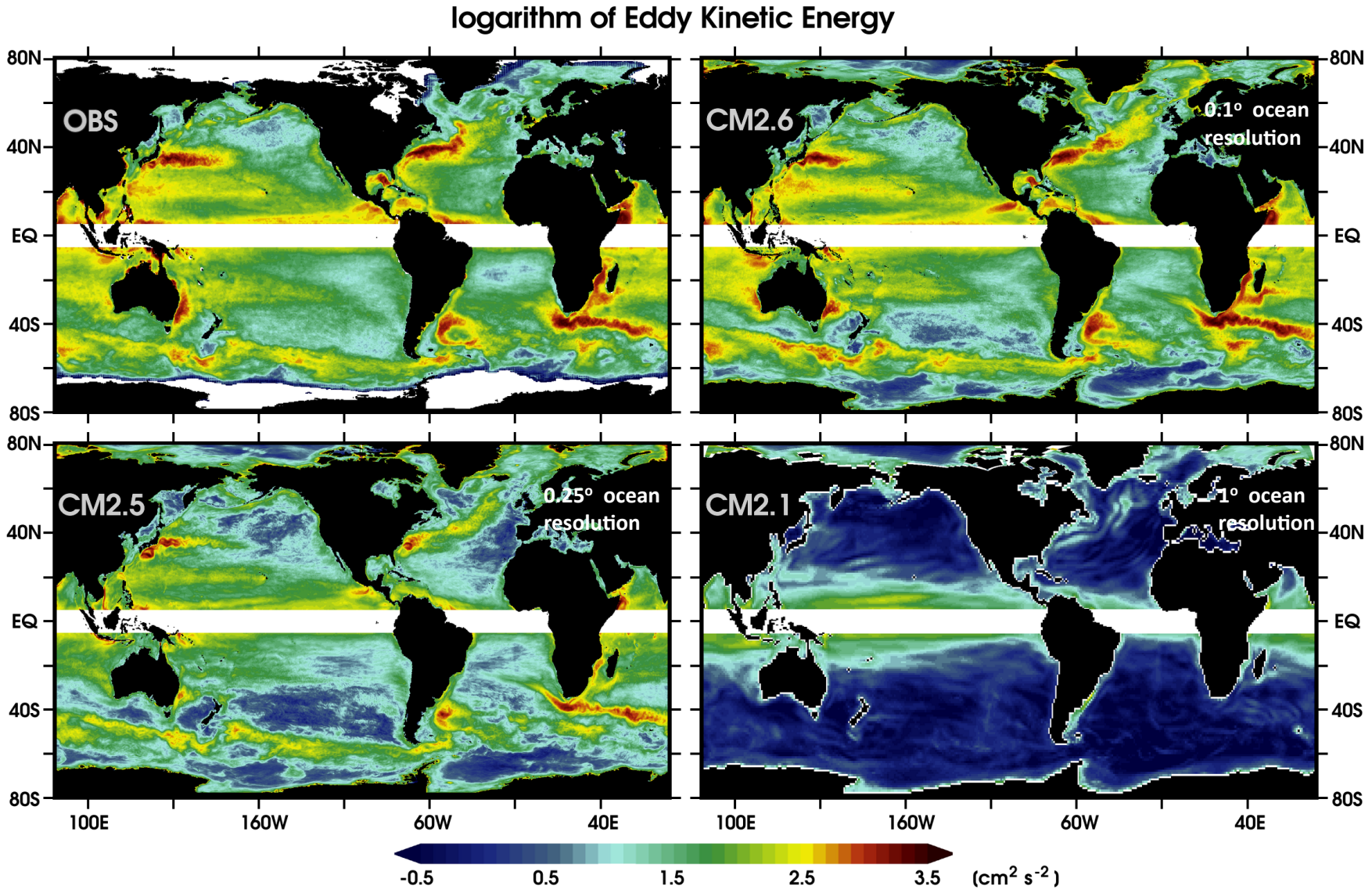
Yang et al., submitted

Some important challenges

1. Changing observational network
2. Model fidelity
3. Uncertainty in past and future radiative forcing
4. Need to better understand mechanisms of decadal variability

2. Model fidelity may be crucial for simulation of oceanic decadal variability and decadal predictions

Eddy kinetic energy in models and estimated from observations



Summary

1. GFDL has developed a unified seasonal to decadal prediction system, and conducted a large ensemble of hindcasts and predictions. Model output available at http://nomads.gfdl.noaa.gov:8080/DataPortal/cmip5.jsp

2. Most of the decadal predictability is associated with the response to external radiative forcing (but how dependent is this result on model and observing systems?)

3. The initialization enhances prediction skill for decadal variability in the North Atlantic

4. Substantial challenges remain, including:
   - Improving models and assimilation systems for decadal variability and predictions
   - Sustaining and enhancing the observing system and dealing with changing observing systems
   - Improved understanding of the mechanisms underlying decadal variations

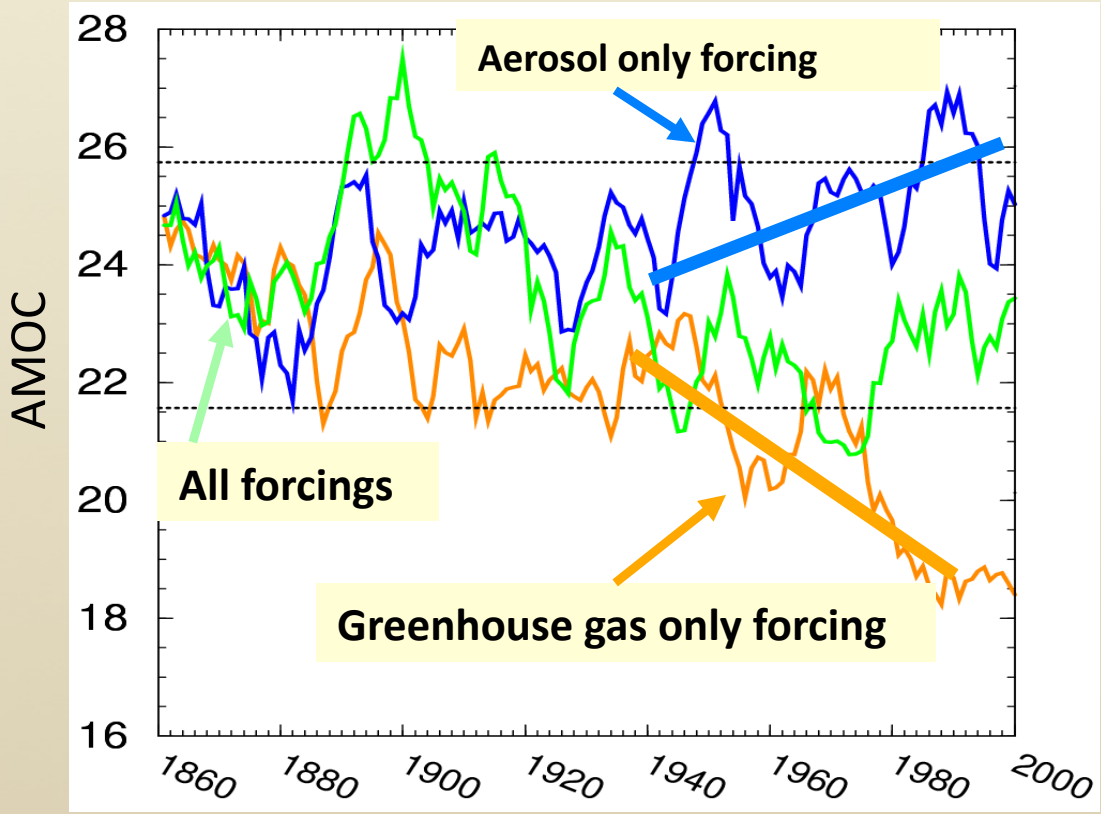
However … the utility of decadal predictions and attribution could be significant.

- *early warning system for potentially abrupt climate change*

- *attribution of observed multiannual to decadal climate fluctuations, such as drought and extreme events (eg, SW US drought, Arctic climate change, etc)*

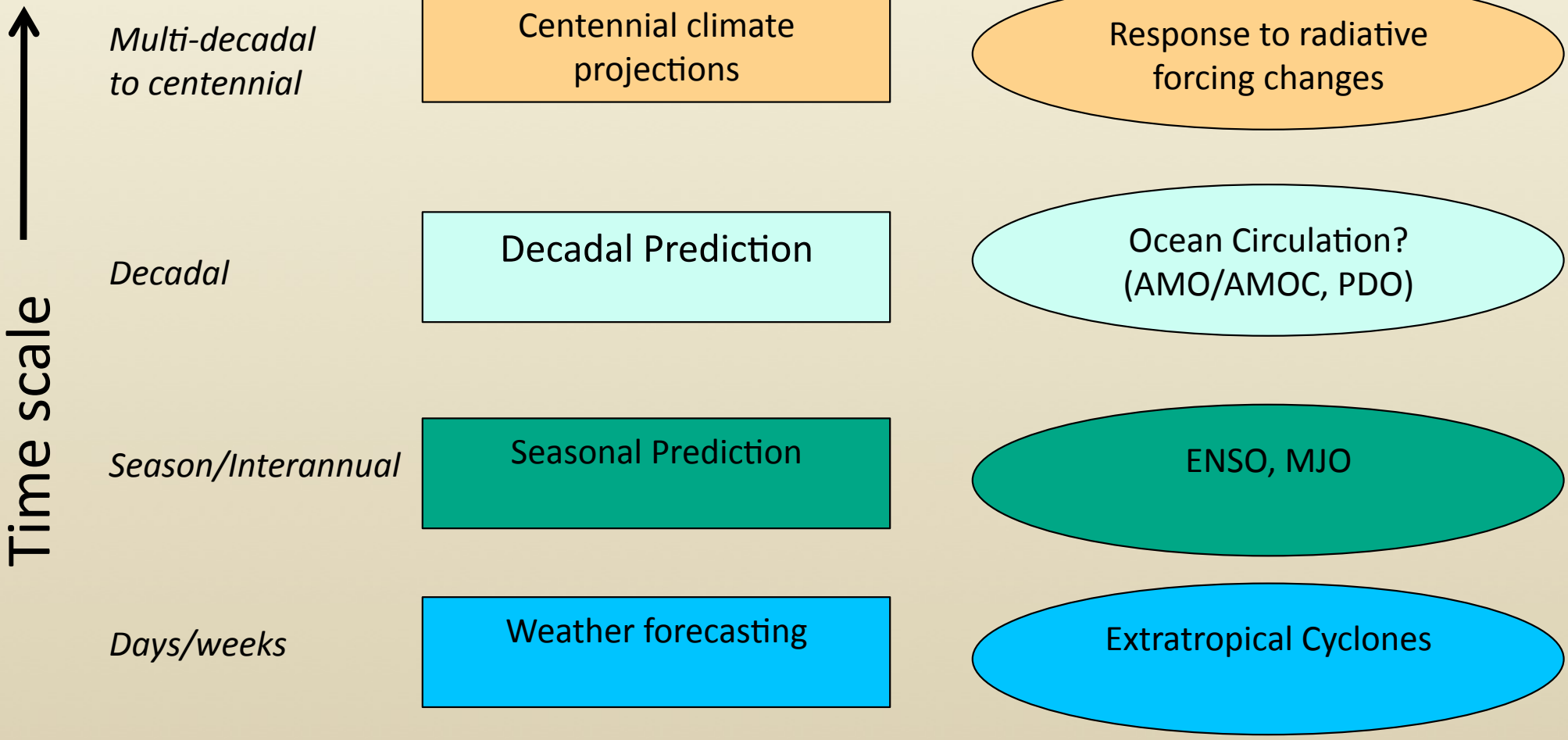
3. Uncertainty in radiative forcings

Uncertainty in radiative forcings (past and future) can be a significant source of uncertainty in decadal predictions, particularly **aerosols**.

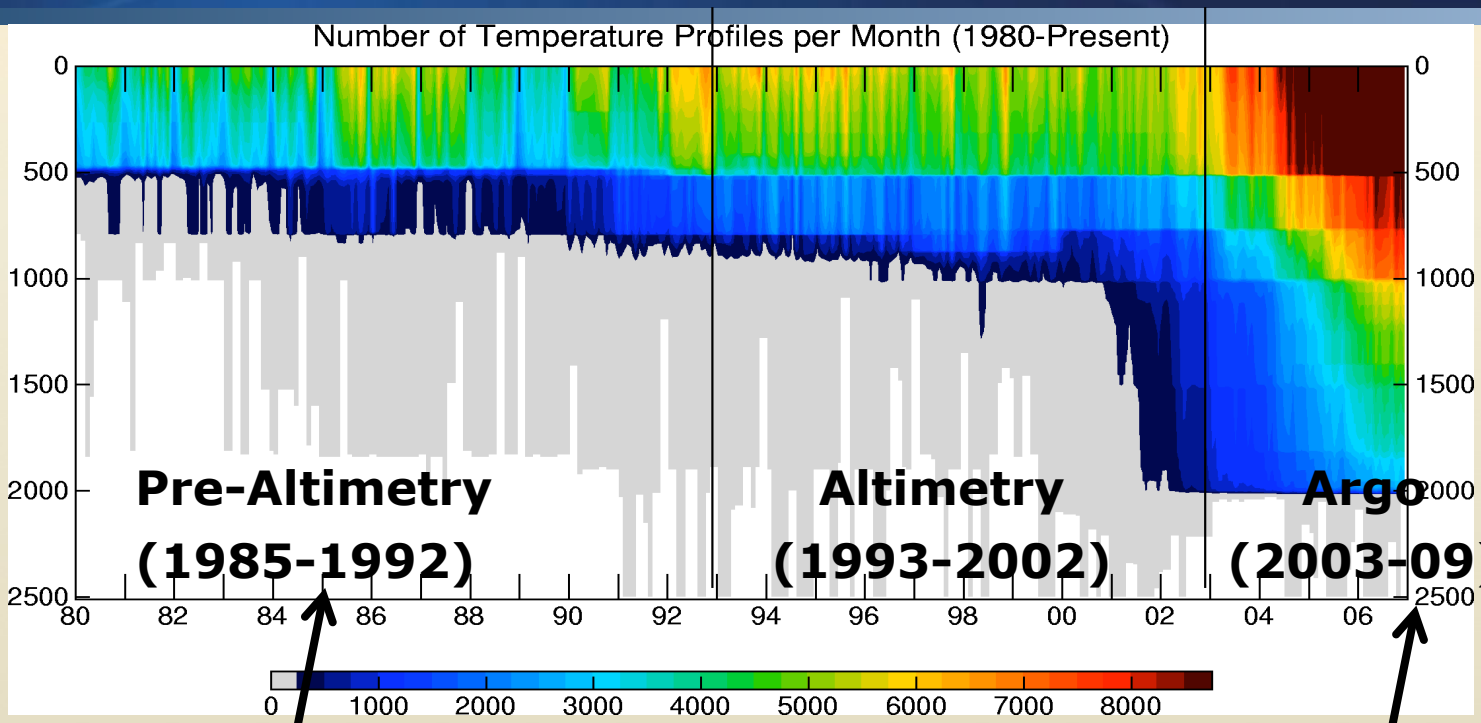


Delworth and Dixon, 2006

Some phenomena that are relevant for predictions and projections



1. Changing observational network



Saha et al. (2010)